The Relative Susceptibility of the Larvae of *Spodoptera mauritia acronyctoides* (Guenée) (Lepidoptera: Noctuidae) to Several Contact Insecticides[1]

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The lawn armyworm, *Spodoptera mauritia acronyctoides* (Guenée), is believed to have been inadvertently introduced into Hawaii by aircraft from either Guam or Fiji. It was first discovered in a light trap near Barber's Point, Oahu, in December, 1953, and within a year, it had established itself as one of Hawaii's most serious lawn pests (Anonymous, 1954; Pemberton, 1955; Tanada, 1955). Although it is reputed to be a pest of rice, sugar cane, and other grasses in the Oriental, Indo-Australian, and Pacific regions, the armyworm in Hawaii primarily attacks Bermudagrass, *Cynodon dactylon* (L.) Persoon (Sherman, 1956; Bess and Ota, 1957).

The biology of the lawn armyworm in Hawaii was studied by Tanada and Beardsley (1958). Adults of the lawn armyworm are nocturnal and are strongly attracted to lights. Adult females lay their eggs in masses on shrubs, trees, and on the eaves of houses in close proximity to the lawn. The egg masses are densely covered by hair scales from the terminalia of the female abdomen. The eggs hatch in approximately 3 to 4 days, and the newly hatched larvae descend to the ground by means of a silken thread. There are 7 or 8 larval instars depending on ecological conditions. They become full grown in approximately one month and pupate in the soil before emerging 2 weeks later as adult moths. The entire life cycle spans 40 to 50 days.

Sherman (1956) rcommended DDT and chlordane sprays to control this pest. Bess and Ota (1957) showed that of the two, DDT is more effective in the field. However, there is a lack of basic toxicological information on the effect of various types of insecticides on this insect. This study was undertaken to determine the susceptibility of several of the larval instars of this insect to typical chlorinated hydrocarbon, carbamate and organophosphorous insecticides.

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Materials and Methods

The larvae of the lawn armyworm used in this experiment were reared in the laboratory at mean temperatures ranging between 23.0° and 30.0 °C The entire test population was propagated from a single egg mass collected on the University of Hawaii campus on June 16, 1960. Glass jars of various sizes and metal boxes of $5 \times 11 \times 14.5$ inches were used for rearing the larvae. The larvae were fed on the tender young leaves of Napiergrass, *Pennisetum purpureum* Schumach, throughout their life. Cages, similar to those illustrated by Peterson (1959), were used for adult emergence.

The adults collected from these cages were kept in wide-mouth gallon jars for oviposition and were given 5% honey-water as a diet and crumpled paper toweling as oviposition sites. The deposited egg masses were collected from the paper toweling and transferred to one-pint Mason jars for hatching. Approximately 200 eggs were placed in each jar. As soon as the eggs hatched, the larvae were fed tender leaves of Napiergrass.

Each jar was sealed with a screw cap which was cut open in the center. A sheet of paper toweling was placed under this screw cap to prevent the larvae from escaping.

When the majority of the larvae reached the 3rd instar, they were transferred from the Mason jars to wide-mouth gallon jars. Paper toweling was placed in these gallon jars to increase the surface area and to absorb any excess moisture. The jars themselves were sometimes cleaned by removing the excreta and the leaf debris, which collected on the paper towelling.

When the majority of the larvae reached the 6th instar, they were once again transferred, this time to the iron boxes, and left there to complete development and pupate among the excreta and leaf debris. To facilitate the cleaning of the rearing boxes, a grate made of a wooden frame and one-half-inch mesh galvanized wire screen was used. Each grate was fixed inside one of these boxes, 2 inches above the bottom. Food was placed on the grate, allowing the larval excreta and leaf debris to drop through the wire screen to the bottom of the box where paper toweling was placed to absorb any excess moisture. Escape of the larvae from the box was prevented by proper placement of a tight-fitting lid made of a wooden frame and fine metal screen.

Occasionally, for the purpose of obtaining egg masses, pupae were collected from the box and placed in a petri dish with moistened paper toweling at the bottom to protect them from desiccation. The petri dish containing the pupae was stored in the emergence cage previously described. Usually, the pupal stage took 8 days for females and 10 days for males. Female adults started to lay eggs 2 or 3 days after emergence.

This technique was adequate for providing sufficient numbers of larvae in the required stages for test purposes. Cannibalism was seldom observed among the insect population, even after the grass in the rearing containers had been completely consumed.

Since both a polyhedrosis virus disease and a microsporidian disease occur among the armyworm population on Oahu (Tanada and Beardsley, 1957, 1958; Tamashiro, 1961) smears of egg masses, larvae, and adults picked up at random from the laboratory culture were prepared to determine if they were infected in order to avoid contamination of the laboratory culture. All the jars that were used for rearing were sterilized in an autoclave at a pressure of 15 psi and a temperature of 120 °C for 20 minutes.

In spite of these precautions, outbreaks of the microsporidian disease occurred 3 times in the insect population during this study. The infected larvae were easily distinguished from the others. Their appearance was somewhat milky and overall development was greatly retarded. Usually, symptoms of disease became noticeable during the 5th or 6th instar. In smears of the infected larvae, many oval shiny spores of *Nosema* sp. were observed; the infected larvae usually died prior to pupation. Even in the jars containing infected larvae, there were some larvae without the symptoms of disease. Since the original population showed no symptoms of disease, it is probable that the disease was accidentally introduced via the food material.

When the disease occurred, the entire insect population in such jars was destroyed. Smears of sample larvae, which were taken from the other jars in which the larvae did not have any symptoms of the microsporidian disease, were prepared and carefully checked under a microscope to see whether spores were present. Test larvae all came from populations which, when sampled, appeared to be disease-free.

The susceptibility to the tested insecticides of the 5th-, 7th-, and 8th-instar larvae, and the prepupae was determined. The 1st-, 2nd-, 3rd-, and 4th-instar larvae were not used since they were too small to be treated topically by the micropipette utilized in this study.

Before this study was carried out a preliminary life cycle study of the lawn armyworm was made in order to be able to separate the various instars so that only larvae of a given instar were included in a single test.

Criteria used in this study for separating the 5th-, 7th-, and 8th-instar larvae were as follows:

Fifth-instar larvae.—The body color of the 5th-instar larva is light green without the longitudinal rows of black dots on the dorsum which are characteristic of the larvae older than the 6th instar. In some individuals, the body color is somewhat purple-green. Although the general appearance of the 5th-instar larva is similar to that of the 4th-instar larva, the 5th-instar larva is generally distinguished by the color pattern of the head capsule. The head capsule of the 4th-instar larva is light tan all over, whereas that of the 5th-instar larva is somewhat darker on the lateral margins of the head and with the frons light tan. Usually the 5th-instar larvae have long white longitudinal bands on the lateral margins of the thorax and abdomen, but in some individuals these bands are brown. The width of the head capsule is about 1.5 mm. The 5th instar usually starts

about 12 days after hatching and lasts 3 to 4 days under laboratory conditions. Since the 6th-instar larva acquires the fundamental pattern of stripes and markings characteristic of the mature armyworm, the 5th-instar larva is easily distinguished from the 6th-instar larva.

Seventh-instar larvae.—The majority of the 6th-instar larvae are green in body color, but the 7th-instar larvae are dark brown with the typical color and markings of the mature armyworm. The rows of black dots on the dorsum are very conspicuous. Width of the head capsule is about 2.5 mm. This instar starts about 20 days after hatching and lasts 3 to 4 days under laboratory conditions.

Eighth-instar larvae.—The 8th-instar larvae are usually darker in body color and much larger than the 7th-instar larvae. Width of the head capsule is about 3.0 mm. This instar starts about 23 days after hatching and lasts about 3 to 4 days before the prepupal stage.

Tanada and Beardsley (1958) studied the life cycle of the lawn armyworm and described the morphological characteristics of each larval instar. The characteristics they described for the 4th-, 5th-, 6th-, and 7th-instar larvae corresponded to the 5th-, 6th-, 7th-, and 8th-instar larvae, respectively, of the present study.

It is known that the number of larval instars may vary within a species depending on environmental conditions and type of food available (Gaines and Campbell, 1935). The occurrence of variation in the quality of food was inevitable in this study, since the leaves of the Napiergrass were taken from an open field. Despite the fact that the morphological differences between the larval instars appeared to be distinct, there is the possibility that larvae classified as belonging to a particular instar may in actuality belong to the preceding instar.

Prepupae.—In this stage, the larvae stop feeding and start to crawl around in the rearing boxes seeking pupation sites. They become thinner and pinkish in body color. They chew the excreta and leaf debris into small bits and fasten those bits together with silk to make loose cocoons in which they pupate. When a cocoon is broken shortly after it is spun, the prepupa inside starts to crawl around again. However, just before molting, the body becomes shrunken and the prolegs shorten and lose their shape so that it becomes the typical prepupa. Prepupae were used for testing just prior to molting. This stage lasted about one day.

Five insecticides were included in this study. These were: chlordane (1, 2, 4, 5, 6, 7, 8, 8-octachloro-2, 3, 3a, 4, 7, 7a-hexahydro-4, 7-methanoindene), technical, sp g (25°C), 1.61; DDT (1, 1, 1-trichloro-2, 2-bis (*p*-chlorophenyl) ethane, technical, 77.2% p,p'isomer, setting pt., 93.2°C; carbaryl (1-naphthyl N-methylcarbamate), technical, 95%, mp 136.4–142.8°C; fenthion (0, 0-dimethyl 0-[4-(methylthio)-*m*-tolyl]phosphorothioate), technical; and malathion (S-[1, 2-bis (ethoxycarbonyl) ethyl] 0, 0-dimethyl phosphorodithioate), premium grade, 95%.

Stock solutions of these materials dissolved in acetone were prepared, and dilutions, with acetone, of these stock solutions were used in all experiments.

Prior to treatment, the insects were transferred from the rearing container into a clean wide-mouth gallon jar with crumpled paper toweling, and kept without food for 3 to 4 hours in order to avoid the effect of recent feeding on the weight of the test population. The insects were then divided into replicated groups of 10. Attempts were made to use individual larvae of approximately the same size within each replicate, and they were weighed in groups of 10. The average weight per individual was used to calculate the dosage of the insecticide applied. All insects were anaesthetized by exposing them to CO_2 just before treatment.

Insecticides were applied to the dorsum of the thorax by means of a microsyringe modified from that described by Roan and Maeda (1953). The volume of the insecticide solution per insect was 0.001 ml, although in some cases, especially in treating 8th-instar larvae with chlordane and carbaryl, the volume had to be increased to 0.006 ml per insect because of the high dosage required. The control insects were treated with the same volume of acetone as were the insecticide-treated insects.

As soon as the acetone had evaporated, the insects were transferred into clean one-pint Mason jars with fresh food. Each jar contained a replicate consisting of 10 insects. These jars were kept on their sides and contained a piece of paper toweling at the bottom to facilitate cleaning the jars.

Prepupae collected from the bottom of the rearing boxes were first cleaned by dipping them in water, after which they were dried on paper towelling. Attempts were made to use individual prepupae that were approximately in the same condition; thus, those which started to crawl around when being cleaned and dried were discarded and only those which were about to molt were used as test animals. The prepupae were treated in the same manner as the larvae. The volume of chlordane solution also had to be increased to 0.006 ml per prepupa.

After the insecticide was applied, the treated prepupae were transferred to a petri dish in groups of 10 per replicate. Water was added to the petri dishes when necessary to maintain adequate humidity for the insects.

As the prepupal stage usually lasted only one day, the majority of the surviving prepupae usually pupated on the day following treatment. The insects were observed 3 days after treatment and classified into one of the following 3 observational categories: (1) Normal, which included slightly affected prepupae and pupae which were normal in appearance; (2) Badly affected, which included abnormal appearing prepupae and pupae, which are described below; and (3) Dead.

All mortality data were taken 3 days after treatment. The badly affected and moribund insects were recorded as dead although actual death did not necessarily occur until a later period. All mortality data were

corrected for natural mortality by Abbott's formula (Abbott, 1925). The median-lethal dosages (LD_{50}) of the insecticides based on the mean body weight of the insects and their fiducial limits at the P=0.05 level were calculated by the method described by Finney (1952).

RESULTS AND DISCUSSION

Toxicity to the larvae.—Table 1 summarizes the toxicity of the insecticides used to the 5th-, 7th-, and 8th-instar larvae in terms of the median-lethal dosages (LD_{50}) and their fiducial limits at a level of P=0.05. The dosage-mortality regression lines of the insecticides for each instar are also given in the table.

TABLE 1. *Summary of the contact toxicity of insecticides to the larvae of* Spodoptera mauritia acronyctoides *three days after treatment*

Insecticide	Median lethal dosage (μg/g)	Fiducial limits P=0.05	Dosage-mortality regression equation
		5th-instar larvae	
Chlordane	354.3	297.9— 421.5	Y=—4.4668+3.7080X
DDT	13.8	12.6— 15.0	Y=—1.0018+5.2714X
Fenthion	38.8	35.6— 42.4	Y=—3.4084+5.2905X
Malathion	36.8	34.3— 39.5	Y=—3.6185+5.5022X
Carbaryl	28.7	23.0— 35.7	Y= 1.8377+2.1696X
		7th-instar larvae	
Chlordane	414.1	360.4— 475.9	Y=—5.4433+2.8872X
DDT	39.1	33.0— 46.4	Y=—1.6275+2.5565X
Fenthion	54.3	43.4— 67.8	Y=—0.6752+3.2722X
Malathion	47.3	40.3— 55.5	Y= 0.0742+2.9409X
Carbaryl	91.3	74.3— 112.2	Y=—0.0907+2.5966X
		8th-instar larvae	
Chlordane	759.9	688.3— 838.9	Y=—9.9617+5.1937X
DDT	54.9	23.3— 129.5	Y=—0.1390+2.9537X
Fenthion	62.4	52.9— 73.7	Y=—1.3854+3.5565X
Malathion	53.2	46.1— 61.5	Y=—0.6994+3.3017X
Carbaryl	122.6	108.9— 138.1	Y=—6.9502+5.7216X

The relative toxicity of the insecticides to the 5th-instar larvae in order of decreasing toxicity was as follows: DDT>carbaryl>malathion=fenthion > chlordane. The relative order of toxicity of the insecticides to the 7th-instar larvae was as follows: DDT=malathion=fenthion>carbaryl> chlordane. To the 8th-instar larvae this order was: malathion=DDT= fenthion>carbaryl>chlordane, but there was no significant difference between the toxicity of DDT and that of carbaryl.

In comparing the relative toxicity of the insecticides to the larvae of each instar, toxicity indices as described by Sun (1950) were employed.

DDT was taken as the standard insecticide and given an arbitrary value of 100 as its index. All insecticides having toxicity indices greater than 100 are that much more toxic than DDT to that larval instar and those having lower indices are less toxic than DDT. The toxicity indices of the remaining insecticides were: for the 5th-instar larvae—chlordane, 4; fenthion, 35; malathion, 37; and carbaryl, 48; for the 7th-instar larvae—chlordane, 10: carbaryl, 43; fenthion, 72; and malathion, 83; and for the 8th-instar larvae—chlordane, 7; carbaryl, 45; fenthion, 88; and malathion, 103.

In general, fenthion, DDT, and malathion were the most toxic insecticides to the 5th-, 7th-, and 8th-instar larvae of the lawn armyworm. DDT was significantly more toxic to the 5th-instar larvae than fenthion and malathion;however, DDT showed toxicity of the same level as fenthion and malathion to the older instars. This certainly confirms the superiority of DDT over chlordane as observed in the field by Bess and Ota (1957).

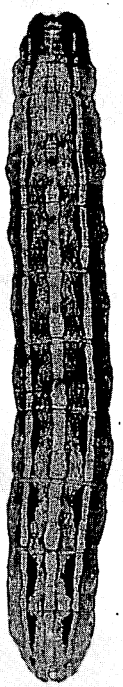

Fig. 1. *Eighth-instar larvae. Left, normal larva; right, larva after insecticide treatment.*

TABLE 2. *Summary of the contact toxicity of insecticides to the prepupae of* Spodoptera mauritia acronyctoides *three days after treatment*

Insecticide	Median lathal dosage (μg/g)	Fiducial limits P=0.05	Dosage-mortality regression equation
Chlordane	>19,000.0	——	——
DDT	302.0	251.1— 363.1	Y=−4.4634+3.8123X
Fenthion	39.4	23.7— 65.4	Y= 2.8834+1.3268X
Malathion	39.2	31.6— 48.7	Y= 0.1885+2.9907X
Carbaryl	2.1	1.6— 2.7	Y= 3.1024+5.8273X

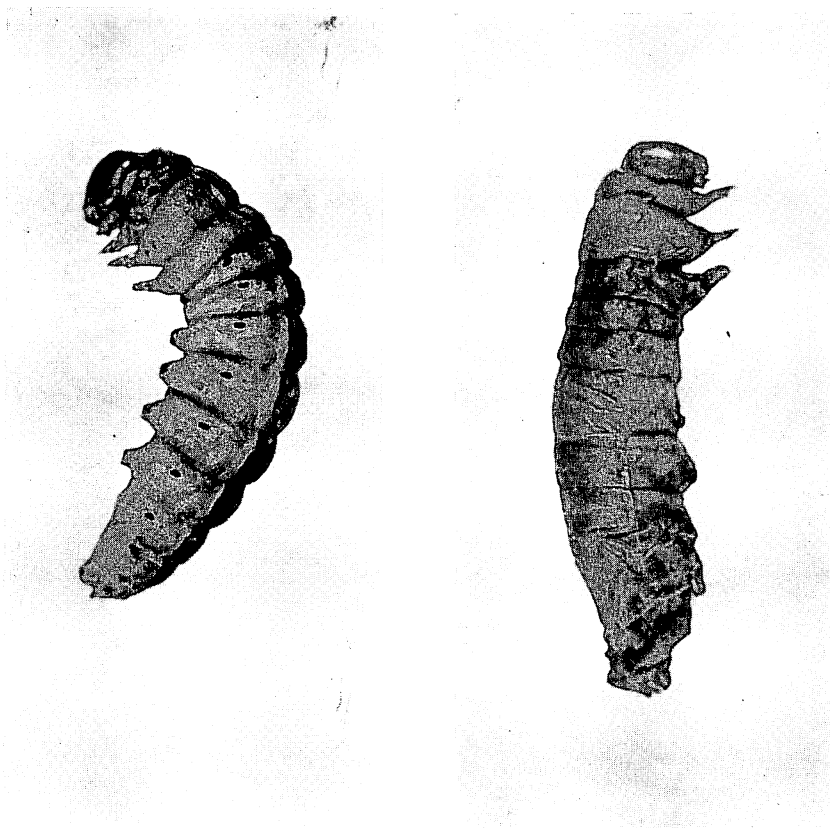

Fig. 2. *Prepupae. Left, normal prepupa; right, prepupa after insecticide treatment.*

These laboratory trials suggest that fenthion and malathion may also be extremely effective in controlling the worm in the field.

The relative susceptibility of the larval instars to each insecticide in decreasing order was as follows: the 5th instar>the 7th instar=the 8th instar to fenthion, DDT, malathion, and carbaryl and the 5th instar>

the 7th instar>the 8th instar to chlordane. This indicates that the older larval stages are more resistant to the insecticides than the earlier larval instars. Similar results have been obtained with other lepidopterous larvae (Yoshida, 1948; Weinman and Decker, 1951; Mukerjea, 1953; Guthrie, 1954; Ichinose and Ishii, 1955; Ishikura and Ozaki, 1955; McPherson *et al.*, 1956; Gast, 1959).

After application of a lethal dose of insecticide, fenthion, DDT, and malathion had a much faster toxic action than did chlordane or carbaryl. Larvae treated with lethal doses of fenthion, DDT, and malathion usually stopped feeding and started to eject a green fluid within an hour and the majority of these larvae were dead within 24 hours after treatment. Shrinkage in poisoned larvae was pronounced (Fig. 1).

Toxicity to the prepupae.—Table 2 summarizes the toxicity of the insecticides to the prepupae in terms of the median-lethal dosages andutheir fiducial limits at a level of P=0.05. The dosage-mortality regression lines are also given in the table.

Fig. 3. *Pupae. Left, normal pupa; right, pupa after treatment with insecticide in prepupal stage. Note short wing pads.*

The relative toxicity of the insecticides to the prepupae was as follows: carbaryl > malathion = fenthion > DDT > chlordane. This order of susceptibility of the prepupae to the insecticides was quite different from that observed in the larvae. Chlordane was ineffective against the prepupae. It was impossible to calculate the LD_{50} of chlordane since the data were extremely heterogeneous and could not be plotted with any degree of reliability. It was interesting that carbaryl was extremely toxic to the prepupae in spite of the comparatively low toxicity to the older larval instars. Toxicity indices of the insecticides to the prepupae were: chlordane, < 1; DDT, 100; fenthion, 767; malathion, 770; and carbaryl, 14,447, respectively.

It is interesting to note that the prepupae were less susceptible than the larvae to chlordane and DDT; much more susceptible than the larvae to carbaryl; and equally susceptible to fenthion and malathion as the larvae.

Symptoms of poisoning shown by the prepupae treated with insecticides were observed. Shortly after treatment, the prepupae became very active and rolled about violently. They could not molt, but their bodies started to harden so that they appeared abnormal (Fig. 2). Usually they remained alive 2 to 4 days, showing feeble movement when disturbed, before they finally died.

Pupae developing from prepupae treated with insecticides were sometimes morphologically abnormal. In such cases, the arrangement of the wings, mouth parts, and legs were irregular in comparison to normal pupae (Fig. 3). Although the majority of these abnormal pupae reached the adult stage, they could not free themselves from the pupal case and, as a result, died.

SUMMARY

The lawn armyworm is one of the most serious pests of lawns in Hawaii, particularly those planted with Bermudagrass. This insect is believed to have been accidentally introduced into Hawaii from either Guam or Fiji.

This study was undertaken to obtain basic toxicological information on the susceptibility of the various instars of this insect to several types of contact insecticides. The insecticides used were: chlordane, DDT, fenthion, malathion, and carbaryl. The contact toxicity of the insecticides were evaluated against the 5th-, 7th-, and 8th-instar larvae and against the prepupae.

The insecticides most toxic to the larval stages were fenthion, DDT, and malathion. DDT was particularly toxic to the 5th-instar larvae. Chlordane was the least toxic insecticide. Tolerance of the larvae to the contact insecticides appeared to increase in the later larval instars.

There was a sudden change in the susceptibility of the insects to the insecticides between the larval stages and the prepupal stage. Chlordane was particularly ineffective against the prepupae and DDT was less toxic

to the prepupae than to the larvae. Carbaryl, on the other hand, was much more toxic to the prepupae than to the larvae. Fenthion and malathion appeared to be equally toxic to the larvae and prepupae.

Abnormal pupae often resulted from treating the prepupae with insecticides and most of these abnormal pupae failed to free themselves from the pupal case when they reached the adult stage.

REFERENCES

ABBOTT, W.S. 1925. A method of computing the effectiveness of an insecticide. J. ECON. ENT. 18(2):265–267.

ANONYMOUS. 1954. Insect reports. HAWAIIAN SUGAR PLANTERS' ASSOC., EXPT. STA. COMMITTEE, 1954 REPORTS: 32–33.

BESS, H.A. AND A. OTA. 1957. The lawn armyworm and its control. HAWAII FARM SCIENCE. 5(3):4–5.

FINNEY, D.J. 1952. Probit analysis, a statistical treatment of the sigmoid response curve. 2nd ed., pp. 236–245. CAMBRIDGE UNIV. PRESS, LONDON AND NEW YORK.

GAINES, J.C. AND F.L. CAMPBELL. 1935. Dyar's rule as related to the number of instars of the corn earworm, *Heliothis obsoleta* (Fab.), collected in the field. ANN. ENT. SOC. AMER. 28:445–461.

GAST, R.T. 1959. The relationship of weight of lepidopterous larvae to effectiveness of topically applied insecticides. J. ECON. ENT. 52(6): 1115–1117.

GUTHRIE, F.E. 1954. Laboratory studies of the toxicity of thirteen insecticides to the tobacco hornworm. J. ECON. ENT. 47(2):215–218.

ICHINOSE, T. AND S. ISHII. 1955. The toxic effect of DDT to the larval instars of the cabbage armyworm, *Barathra brassicae* L. OYO-KONTYU. 11(1):1–7. (In Japanese with an English summary.)

ISHIKURA, H. AND K. OZAKI. 1955. Relation between the resistance to ethylparathion of the cabbage armyworm and the larval stage,age, and food plant. BOTYU-KAGAKU. 20(4):121–126. (In Japanese with an English résumé.)

MCPHERSON, J.E., L.D. NEWSOM, AND J.S. ROUSSEL. 1956. Response of *Heliothis zea* (Boddie) and *H. virescens* (F.) to DDT and endrin in laboratory toxicity studies. J. ECON. ENT. 49(3):368–371.

MUKERJEA, T.D. 1953. The relationship between the stage of development and susceptibility to DDT and the pyrethrins of *Diataraxia oleracea* (L.), *Tenebrio molitor* L., and *Periplaneta americana* (L.). BULL. ENT. RES. 44(1):121–161.

PEMBERTON, C.E. 1955. Notes and exhibitions. PROC. HAWAIIAN ENT. SOC. 15(3): 373.

PETERSON, A. 1959. Entomological technique, how to work with insects. 9th ed., pl. 19, Fig. 5. EDWARDS BROTHERS, INC., ANN ARBOR, MICH.

ROAN, C.C. AND S. MAEDA. 1953. A microdevice for rapid application of toxicants to individual insects. BEPQ, USDA ET-306:1–3.

SHERMAN, M. 1956. Control of the lawn armyworm. HAWAII FARM SCIENCE. 4(4):1, 7.

SUN, Y.P. 1950. Toxicity index—an improved method of comparing the relative toxicity of insecticides. J. ECON. ENT. 43(1): 45–53.

TAMASHIRO, M. 1961. Microsporidioses of some insects in Hawaii. Abstracts of symposium papers:193. TENTH PACIFIC SCIENCE CONGRESS, HONOLULU, HAWAII.

TANADA, Y. 1955. Notes and exhibitions. PROC. HAWAIIAN ENT. SOC. 15(3): 384.

TANADA, Y. AND J.W. BEARDSLEY, JR. 1957. Probable origin and dissemination of a polyhedrosis virus of an armyworm in Hawaii. J. ECON. ENT. 50(2):118–120.

——— AND ———. 1958. A biological study of the lawn armyworm, *Spodoptera mauritia* (Boisduval), in Hawaii (Lepidoptera: Phalaenidae). PROC. HAWAIIAN ENT. SOC. 16(3):411–436.

WEINMAN, C.J. AND G.C. DECKER. 1951. The toxicity of eight organic insecticides to the armyworm. J. ECON. ENT. 44(4):547–552.

YOSHIDA, M. 1948. Toxicity of pyrethrin to certain insect larvae at their different stages of growth. BOTYU-KAGAKU. 10:60–68. (In Japanese with an English résumé.)